AREVA

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to U.S. EPR Design Certification Application RAI No. 451, Supplement 2

Ref. 1: E-mail, Getachew Tesfaye (NRC) to Martin C. Bryan (AREVA NP Inc.), "U.S. EPR Design Certification Application RAI No. 451 (5136), FSAR Ch. 6," October 20, 2010.

Ref. 2: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 451, FSAR Ch. 6," November 19, 2010.

Ref. 3: E-mail, Martin C. Bryan (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 451, FSAR Ch. 6, Supplement 1," March 31, 2011.

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. Reference 2 provided a schedule for a technically correct and complete response to RAI No. 451. Reference 3 provided a revised schedule for a technically correct and complete response to the one question (06.02.01.04-8) in RAI No. 451.

The enclosure provides a technically correct and complete FINAL response to Question 06.02.01.04-8. AREVA NP considers some of the material contained in the attached response to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support the withholding of the information from public disclosure. Proprietary and non-proprietary versions of the enclosure to the letter are provided.

The following table indicates the respective pages in the enclosure that contain AREVA NP's final response to the subject question.

Question #	Start Page	End Page
RAI 451 — 06.02.01.04-8	2	28

This concludes the formal AREVA NP response to RAI No. 451, and there are no questions from this RAI for which AREVA NP has not provided responses.

D077
NRO

AREVA INC.
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If you have any questions related to this submittal, please contact me by telephone at 434-832-2369 or by e-mail to sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

Sandra M. Sloan, Manager
New Plants Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: G. Tesfaye
Docket No. 52-020

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, Regulatory Affairs for New Plants, for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in, "Response to U.S. EPR Design Certification Application RAI No. 451, Supplement 2," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information".

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Sandra M. Sloan

SUBSCRIBED before me this 25th

day of May, 2011.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2011
Reg. #110864

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110864
My Commission Expires Aug 31, 2011

Response to

Request for Additional Information No. 451, Supplement 2

10/20/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.01.04 - Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures
Application Section: 6.2.1.4

QUESTIONS for Containment and Ventilation Branch 1 (AP1000/EPR Projects) (SPCV)

Question 06.02.01.04-8:

FOLLOW-UP TO RAI 378, QUESTION 06.02.01-82

This question relates to FSAR Section 6.2.1.4 and concerns main steam line break mass and energy release for containment analysis. The Supplement 3 response to RAI 378 Question 06.02.01-82 is incomplete. The NRC staff requested that AREVA provide the steam generator inventories that were used in the main steam line break containment analyses, to describe how they were determined, made conservative, and verified to be accurate.

AREVA stated that the inventories were determined from the geometric characteristics of the US EPR SG, the operating data and the operating temperatures. The staff requires additional detail as to how this was done in particular how the inventories were determined using the geometric characteristics of the US EPR SGs and how these values were verified against operating data and operating temperatures given that no EPRs are currently now in operation.

Response to Question 06.02.01.04-8:

Presentation of the PERFGV code

Introduction

It is a steam generator (SG) design objective to meet thermal and hydraulic requirements for each 79/19-type U.S. EPRSG at full load, and specifically to meet the two main operating parameters, which are the saturation steam pressure and circulation ratio.

The computer code used to determine thermal hydraulic parameters is PERFGV. It provides the steady state conditions, the thermal hydraulic parameters, and the performance of recirculating U-tube SGs from zero to nominal load at a variety of conditions ranging from clean and no plugging, at beginning of life, to fouled conditions and plugging, at end of life.

Methodology of the code

The code computes the primary operating conditions of the SG (outlet temperature, mass flow rate, primary pressure drop) from the primary input data. The code then determines the secondary saturation pressure by considering the amount of heat yielded by the reactor coolant during its passage through the SG. In an economizer SG model, the overall heat transfer is calculated from individual tube bundle regions: the hot leg, the cold leg, the economizer zone and the U-bend region. The calculation is iterative because the global heat transfer coefficient is dependent upon the secondary side temperature, and also on the circulation ratios in the economizer.

The global heat transfer coefficient is calculated as a function of five basic resistances:

- The resistance of the inner tube wall surface in forced convection, and evaluated by the DITTUS BOELTER correlation.
- The tube wall resistance.

- The resistance at the outer tube wall surface, in the U-bend zone, hot leg and cold leg zones, which is calculated in boiling conditions by using the [ ] correlation.
- The resistance at the outer tube wall surface in the economizer zone using forced heat convection.
- The fouling resistance.

The steam flow rate at the saturation pressure can then be calculated by applying the conservation of energy principle.

The circulation ratios in the hot side and cold side are determined by taking the recirculation loop pressure losses and the recirculation head as being equal.

The circulation head is a result of the difference in the density of the subcooled water in the downcomer, and the density of the water and steam mixture present in the tube bundle, and is dependent on void fraction.

The main pressure losses considered are:

- Due to friction in single or in two-phase flow.
- In the downcomer.
- Due to the opening of the bundle wrapper at the bottom of the tubes.
- Due to cross flow at the bottom of the tube bundle.
- During passage through the tube support plates, in single and in two-phase flow.
- Due to cross flow in the U-bend part of the tubes.
- In the separators.
- Due to the variation in momentum impulse in the evaporation process.

The pressure loss calculations are also iterative because there are two circulation flow paths and two circulation ratios, one for the hot side and for the cold side, with a common region from the top of separation plate to the primary separator outlet.

Once the recirculation loop pressure losses and recirculation head are equalized, the water and steam masses inventory can be calculated. An iterative loop is also necessary to compute the effective heat transfer coefficient in the economizer region.

Mass flow rates in the hot side and the cold side of the tube bundle are obtained from steam flow rate and circulation ratio through the following relations:

$Q_H = CR_H Q_V$ and $Q_C = CR_C Q_V$

where =

Q_H = the mass flow rate in the hot side of the tube bundle,

Q_C = the mass flow rate in the cold side of the tube bundle,

Q_V = the steam mass flow rate,

CR_H = the hot side circulation ratio,

CR_C = the cold side circulation ratio.

The pressure downstream of the separator outlet is determined from the saturation pressure in the U-bend and by accounting for:

- The water head in the separators.
- The pressure drops due to the separators.
- The pressure drop due to flow contraction between the top of the tube bundle and the separator inlet.
- The pressure drop due to flow expansion at the separators outlet.

The pressure at the steam outlet is obtained from the pressure downstream of the separators outlet and accounting for the pressure drops due to the dryers and the flow restrictor.

The feedwater pressure at the SG inlet is equal to the pressure downstream of the separators outlet, plus the head of fluid between the separators outlet and the SG inlet nozzle, plus the pressure losses in the feedwater injection system (deflectors, converging devices, connection tee and elbow).

On the primary side the total pressure loss between the reactor coolant inlet and outlet is the sum of:

- The inlet channel head pressure drop.
- The inlet tube pressure drop.
- The pressure drop inside tubes (friction and elbow pressure drop).
- The outlet tube pressure drop.
- The outlet channel head pressure drop.

The PERFGV code also calculates the water mass in the SG in the liquid and the vapor phase on the downcomer side, as well as on the two-phase boiling side, taking into account the circulation ratio values and void fraction existing in the tube bundle.

Qualification of the PERFGV code

The qualification of the PERFGV code is based on the laboratory and on-site tests and measurements. The obtained results are described in the following paragraphs.

Laboratory test: MEGEVE SG

The MEGEVE SG test loop was designed and built to simulate and qualify the performance of the new AREVA NP SG equipped with an axial economizer, and it also allows simulation of the behavior of boiler type SGs.

Many tests were performed, particularly in steady state operating conditions, including:

- Tests at different loads with a constant water level.
- Tests with different feedwater distributions in hot leg and in cold leg for boiler type SGs.
- Tests with a feedwater distribution of 100 percent in cold leg to simulate axial economizer type SG.
- Tests with a given pressure at different load levels, and tests with a given load level at various steam pressures, to calibrate heat transfer correlations.

The different test measurements associated with the saturation steam pressure in the tube bundle, the pressure drops in the circulation loop, the void fraction in the tube bundle and the circulation ratio allow qualification and validation of the PERFGV code.

The details of the MEGEVE installation, test program and its main results are given in Attachment A.

Saturation pressure prediction in axial economizer configuration

The measurements of saturation pressure on MEGEVE SG show that the difference between calculated pressure and measured average saturation pressure is less than 1.5 psia at full load (see Figure 06.02.01.04-8-A5 Attachment A).

Circulation ratio prediction in axial economizer configuration

For the MEGEVE SG, in loads ranging from 30 percent to nominal, the difference is less than three percent for the hot circulation ratio, less than eight percent for the cold circulation ratio and less than four and a half percent for the global circulation ratio (see Figure 06.02.01.04-8-A7 Attachment A).

Laboratory test: Thermal conductivity of alloy 690

The thermal performance, or steam pressure prediction, of an SG is directly related to the tube material, particularly to its thermal conductivity. The objective of the tests was to obtain the thermal conductivity of alloy 690 with good accuracy.

Methodology of the tests

The methodology is to obtain the thermal conductivity of alloy 690 by comparing it with alloy 600. The ratio of thermal conductivities of the tube materials, $\frac{\lambda_{690}}{\lambda_{600}}$, is obtained by measuring its diffusivity ratio. Because the thermal conductivity of alloy 600 is accurately known, that of the alloy 690 can be deduced.

The following steps constitute the determination of the conductivity from the measured quantities:

1. Measurement of the diffusivity ratio through tube wall in the radial direction
   $\frac{\alpha_{690}}{\alpha_{600}}$
2. Measurement of the specific heat capacity
   Cp_{600}, Cp_{690}
3. From the densities ρ of the two alloys the following conductivity ratio is computed
   $$\frac{\lambda_{690}}{\lambda_{600}} = \left(\frac{\alpha_{690}}{\alpha_{600}}\right) \cdot \left(\frac{\rho_{690}}{\rho_{600}}\right) \cdot \left(\frac{Cp_{690}}{Cp_{600}}\right)$$

Measurement of the diffusivity ratios

Diffusivity measurements are based on the "flash" laser beam method applied on tube samples taken from SG tube standard products. Tests were performed at CEA Laboratory (1990 –1991).

The studied sample is heated in an oven in which temperature increases linearly with time. The sample temperature is measured continuously.

The laser beam produces a flash every 122°F from room temperature to 932°F. The temperature variation in the radial direction of the tube is recorded and is used to calculate the relative diffusivity.

Several samples are used and the experiments are done alternatively on the two materials (Alloys 600 and 690) in order to improve the accuracy of measurement of their relative diffusivity.

Results of laboratory tests confirmation

From the test results it has been determined:

- a measured ratio of specific heat equal to $\left(\frac{Cp_{690}}{Cp_{600}}\right) = 1.015$,
- a mean measured ratio of diffusivities equal to $\left(\frac{\alpha_{690}}{\alpha_{600}}\right) = 0.933$.

Since the ratio of densities is equal to $\frac{\rho_{690}}{\rho_{600}} = 0.97$,

$\frac{\lambda_{690}}{\lambda_{600}} = 0.92$ is obtained.

Since the conductivity of alloy 600 is equal to 10.24 Btu/ft.hr.°F at 572°F, the value deduced for λ_{690} is equal to 9.42 Btu/ft-hr-°F.

This result is confirmed by on-site measurements at DAMPIERRE Unit 1 (900 MWe plant) from the first year after SG replacement (tubes with alloy 690). It corresponds to a decrease of steam pressure at a full load of about 17.4 psia, observed after the replacement of the SGs.

On-site test

This qualification of the PERFGV code is mainly based on the best prediction of two parameters:

- Saturation pressure.
- Recirculation ratios.

Attachment B provides the details and main results of the on-site test program performed on a type 68/19 boiler SG installed in 1300 MWe plants.

Saturation pressure prediction

The determination of saturation pressure depends on:

- Thermal conductivity value of tube material.
- Boiling heat exchange correlation [ ] occurring in the U-bend zone, hot leg and cold leg zones,
- heat exchange in forced convection in the economizer zone.

For thermal conductivity, specific tests have permitted the determination of a best estimate value for alloy 690 (9.42 Btu/ft-hr-°F at 572°F). This value is obtained from the value of alloy 600 thermal conductivity which has been confirmed from performance data in the MEGEVE SG and on more than 50 plants.

The different on-site measurements of steam pressure, which are monthly measurements or fully instrumented SG-special measurements, have demonstrated that the divergence between calculated pressure and measured average saturation pressure is less than 1.5 psi at full load for PAUEL 1 (see Figure 06.02.01.04-8-B6).

Circulation ratio prediction

The circulation ratios in the hot side and in the cold side are determined by PERFGV code, taking the recirculation loop pressure losses and the recirculation head as being equal.

For the determination of pressure drop in the recirculation loop:

- Head loss coefficients are calculated.
- Cross flow in the U-bend region is determined.

The pressure head is calculated, using in particular a [ ]. This correlation is used to improve void fraction prediction as a function of quality, pressure and flow rate and has been qualified by tests performed on the MEGEVE SG (see Figure 06.02.01.04-8-A6).

Based on these different coefficients, the PERFGV code accurately predicts the circulation ratios which were measured on PALUEL 1 SGs.

For PALUEL 1, the divergence is less than two to four percent in load ranging from nominal to 20 percent (see Figure 06.02.01.04-8-B5).

Water mass validation

The PERFGV code can predict the liquid and vapor phase water masses in the SG for different thermal loads from 0% to 100% NP.

These calculations are based on the precise calculated values of the circulation ratio values and the void fraction existing in the tube bundle.

The results for both SG configurations (boiler and economizer) have demonstrated a good agreement in the calculation of the circulation ratio, and a good prediction of the void fraction correlation versus quality based **[**

].

The accurate prediction of these parameters allows the validation of the water mass estimates in the SG and confirms that the model is a good representation of the SG.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

ATTACHMENT A
MEGEVE TESTS

A1 MEGEVE Steam Generator

A1.1 Introduction

AREVA NP initiated a research and development program to design a more compact, efficient and reliable SG. A subsequent joint experimental program called "MEGEVE" was set up by the French Atomic Energy Commission (CEA) and AREVA NP to evaluate the behavior of this new SG, 73/19 TE series.

The MEGEVE program was defined and carried out to simulate the behavior and qualify the performance of axial economizer SGs, and to simulate the behavior of boiler-type SGs.

The test program included a first phase, consisting of steady state tests, which includes steady state parameter verification, stability tests at different water levels and feedwater flow rates, tests of start-up of recirculation in both legs, and a second phase of transient tests, which includes (power steps, reactor trip, house load operation.

The MEGEVE program allowed qualification and validation of thermal-hydraulic computer codes for normal operating conditions (PERFGV) and for transient conditions (adjustment of void fraction, pressure drop and heat transfer correlations).

A1.2 MEGEVE test loop and SG description

A1.2.1 Experimental facility

MEGEVE facility is a pressurized water power plant of 25 MWth with (see Figure 06.02.01.04-8-A1):

- A primary circuit with pressure of 2,250 psia and hot and cold leg temperatures of 617°F and 554°F, respectively.
- A secondary circuit, including the SG (rated pressure equal to 1 100 psia) and a steam circuit in which the turbine is replaced by a discharge valve on top of the condenser.
- An intermediate water system.
- A chemical and volume control loop.
- A third-level system that includes cooling towers.

The nuclear power source is simulated by three oil-fired furnaces heating a molten salt loop which transfers its energy to the primary pressurized water loop via a heat exchanger.

A1.2.2 MEGEVE SG

The SG (see Figure 06.02.01.04-8-A2) was manufactured by AREVA NP using technology as close as possible to that developed for the actual SGs. The main design choices were:

- Full scale in height.
- Full scale in tube length, diameter (three-fourths inch outside diameter), and thickness.
- Tube bundle (149 U-tubes) with triangular pitch (1.08 inch).
- Trifoiled tube support plates.
- Area and volume ratio remain identical to that of SGs (as much as practicable).
- Cylindrical pressure shell over the entire height.
- Capability to adjust pressure drop in the downcomers, allowing the circulation ratios to be monitored.
- Capability to operate either in boiler or in axial economizer SG configurations.

The main geometrical characteristics of the SG are given in Table 06.02.01.04-8-A1.

Table 06.02.01.04-8-A-1—MEGEVE: Main Geometric Characteristics of the MEGEVE Steam Generator

Pressure Shell	
Height	702 in
Internal diameter	30.5 in
Tube Bundle	
Tube bundle diameter	22 in
Tubes number	149
Minimum U-bend radius	1.19 in
Minimum straight length	383.8 in
Heat transfer area	275x103 in^2
Tube diameter (d)	0.75 in
Triangular pitch (p)	1.08 in
p/d	1.44
Number of tube support plates	9
Number of flow distribution baffles	1
Separator	
Separator number	3
Separator nominal diameter	7.87 in
Dryer	
Number of dryer blocks	1
Dryer area	654 in^2
Dryer height	41.1 in
Dryer length	15.9 in

A1.2.3 Instrumentation

The loop and the SG have the following instrumentation.

The loop instrumentation includes:

- Forty-five temperature measurements.
- Eighteen differential pressure measurements.
- Twenty-four flow rate measurements.
- Ten level measurements.
- Fourteen valve position measurements.

This instrumentation allows control of the loop and good performance of the tests. For the thermal-hydraulic studies, the SG had instrumention on both the primary side and the secondary side. On the primary side, the fluid temperature was measured by thermocouples distributed along the tube bundle (seven in the large U-bend and seven in the small U-bend).

On the secondary side, the SG was provided with 77 measurements including:

- Twenty-eight pressure drops (in downcomer, in tube bundle and in separators).

- Four level measurements (narrow and wide range).
- Thirty-two void fraction measurements (in downcomer, in tube bundle and at separator inlet).
- Thirteen flow rate measurements (venturi tubes) used for determinations of:
  - Circulation ratio
  - Feedwater distribution
  - Drier efficiency
- Thirty fluid temperature measurements were also installed in the downcomer (six) and along the tube bundle (Eighteen in cold leg and six in hot leg).

A1.2.4 Steady state operating conditions

A1.2.4.1 Tests realized

Main tests performed for the boiler configuration were:

- Tests at different loads with a constant water level.
- Tests with different feedwater distributions in hot leg and cold leg for boiler type operation.
- Tests at a given load but with different water level to study the effect on circulation ratio.

A1.2.4.2 Results

Before each test series, hot standby was reestablished to verify and validate the continuity of thermal-hydraulic instrumentation. During steady state experiments, the different SG parameters, such as inlet and outlet primary temperatures, primary and secondary flow rates, and secondary steam pressure were stable and verified of the accuracy of the results.

a) Steam pressure in economizer configuration

Figure 06.02.01.04-8-A5 gives the saturation pressure value measured at different load levels from 20 percent to 100 percent full load. These values correspond directly to the operating conditions, particularly to primary temperatures, recorded during the test. The primary temperature does not follow the design temperature program with precision, which explains the reason for which saturation pressure is not always decreasing versus load.

The measurement precision is ± 8.7 psi.

Figure 06.02.01.04-8-A5 also provides the saturation pressure calculated by PERFGV. There is good agreement between test and calculation results. In loads ranging from 20 percent to 100 percent nominal load, the maximum difference is 10 psi and at full load the difference is smaller than 1.5 psi.

b) Void fraction

The pressure drop measurements taken in the straight part of the tube bundle, between two adjacent tube support plates (TSP), and on both sides of each TSP helped determine the void fraction at different elevations of the tube bundle. The pressure drop corresponding to two-phase friction is calculated with the [ ] correlation and is subtracted from the total pressure drop measured.

The quality was determined at the same elevation by accounting for the primary and secondary temperatures measured along the entirety of the tube bundle.

Figure 06.02.01.04-8-A6 gives the evolution of the measured void fraction determined in cold leg and hot leg of the tube bundle versus the measured quality. The numerous data points are in good agreement with the [ ] correlation, taking into account the influence of mass velocity which is plotted on the figure.

c) Circulation ratio in economizer configuration

Venturi tubes were set in the downcomers to accurately determine flow rates in the cold and hot legs, and to calculate the circulation ratios (CR).

The tests results verify the usual evolution of the circulation ratio according to the load level, which is that the CR increases when load level decreases, or when the water level increases, and show that the recirculation loop is established in both hot and cold legs above four percent nominal load.

In evaluating the pressure drop coefficient measured during the test for specific regions, such as.separators, tube support plate, tube bundle entrance and flow distribution baffle, and downcomer, and taking into account the [ ] correlation, Figure 06.02.01.04-8-A7 shows that the circulation ratios calculated with PERFGV fit well with the measured values. In loads ranging from 30 percent to nominal the difference is smaller than three percent for the hot circulation ratio, smaller than eight percent for cold circulation, and less than four and a half percent for the global circulation ratio.

Figure 06.02.01.04-8-A1—MEGEVE Facility

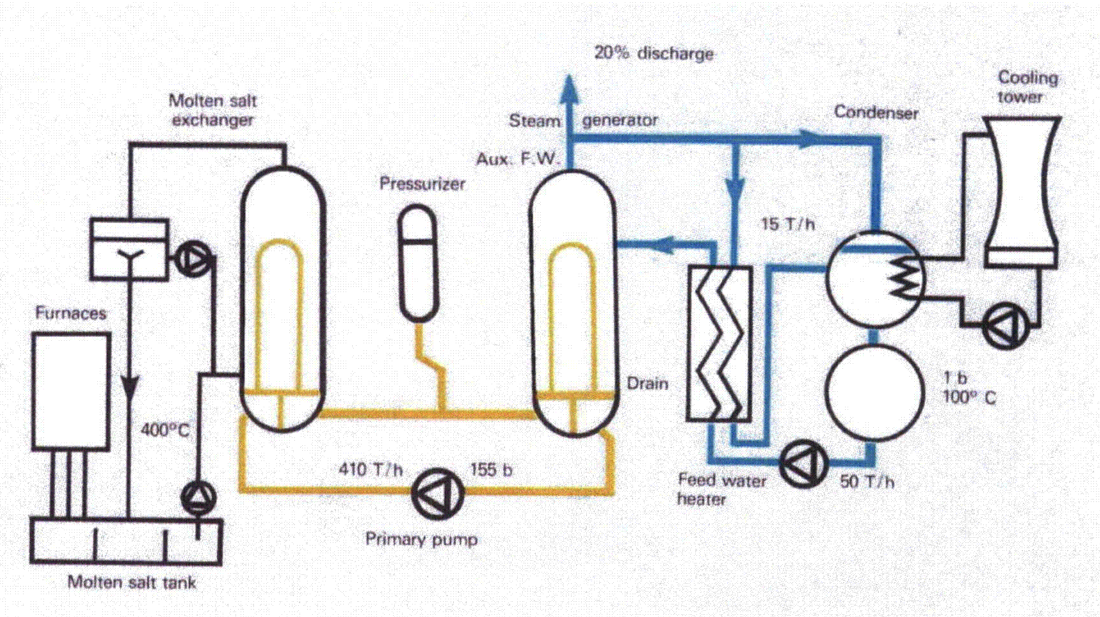


Figure 06.02.01.04-8-A2—MEGEVE Steam Generator Test Loop

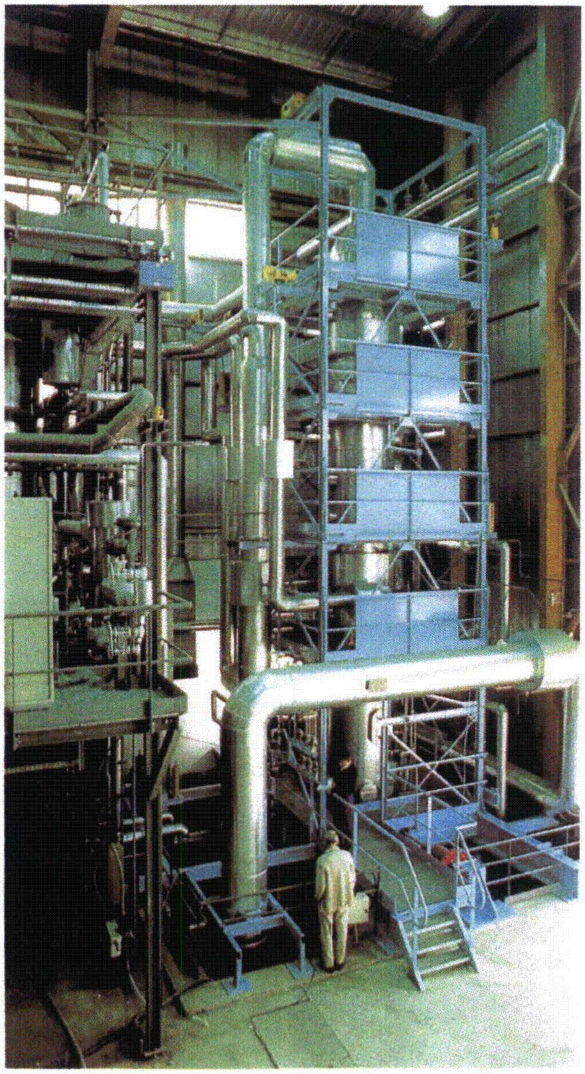
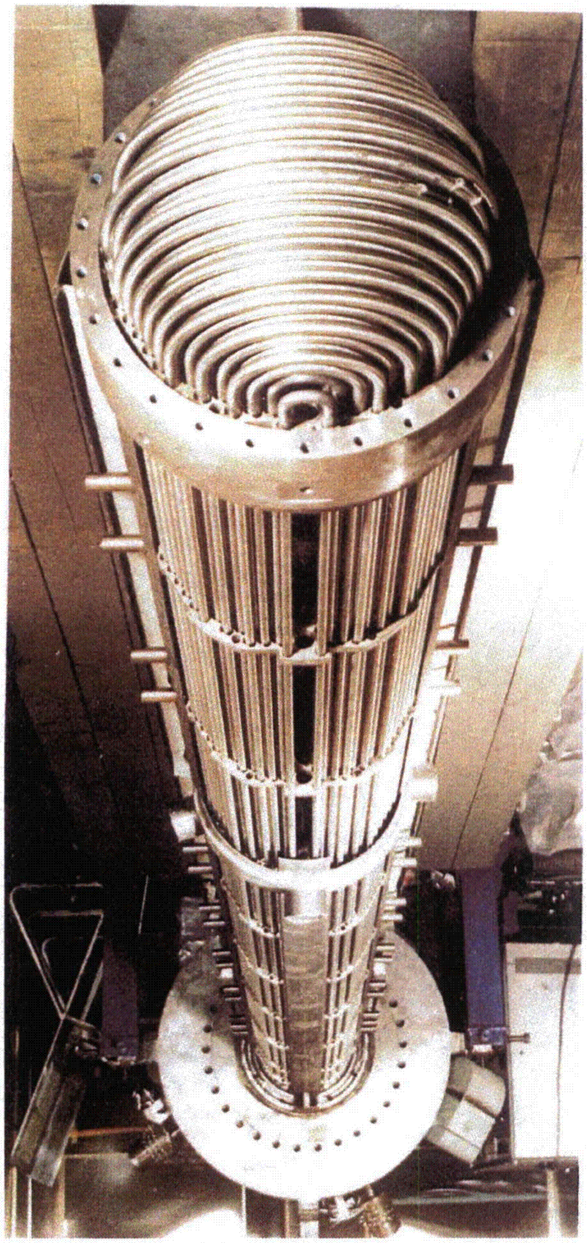


Figure 06.02.01.04-8-A3—MEGEVE Steam Generator Tube Bundle



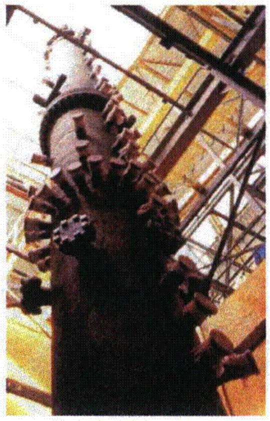


Figure 06.02.01.04-8-A4—MEGEVE Steam Generator

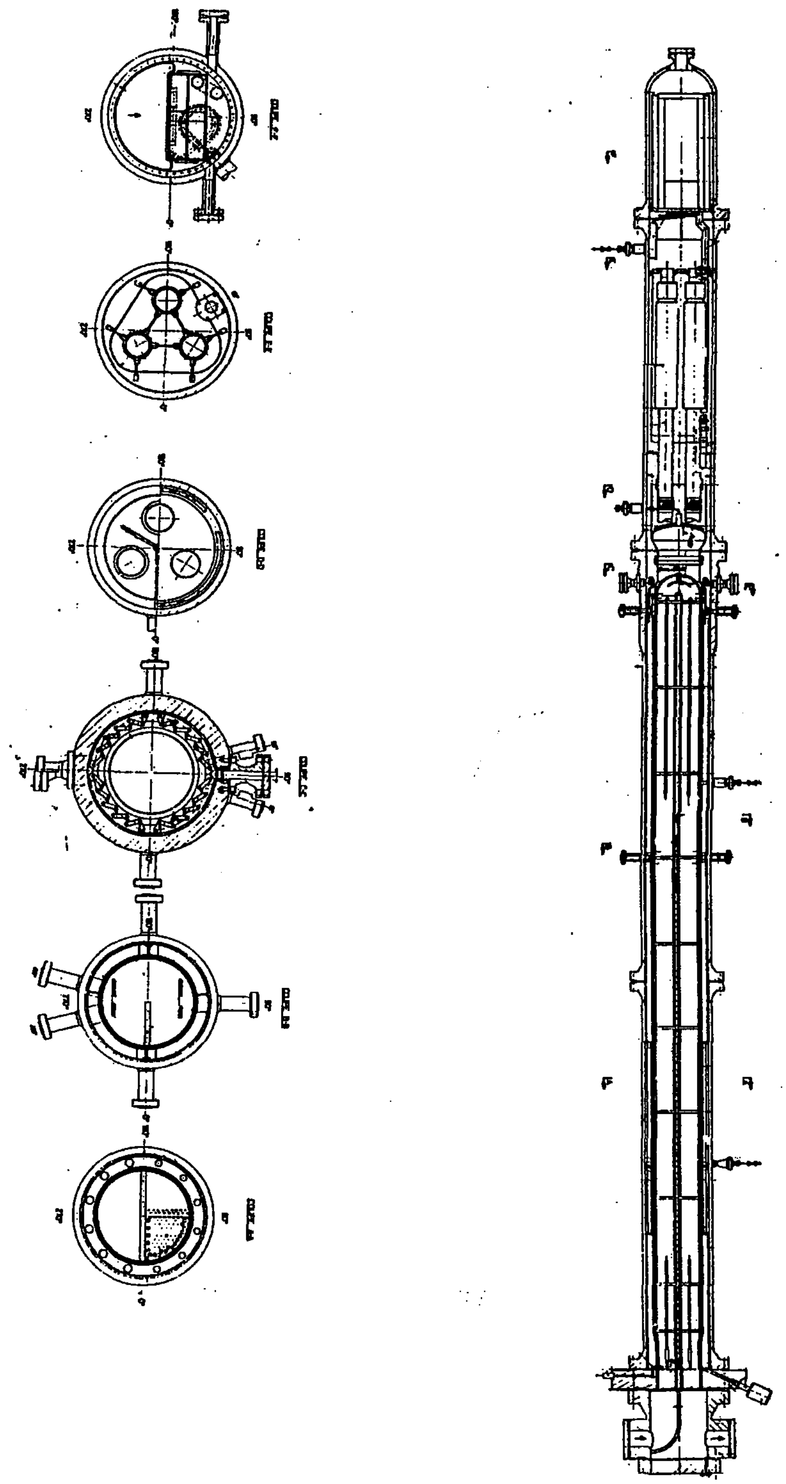


Figure 06.02.01.04-8-A5—MEGEVE Steam Generator – Saturation Pressure

[ ]

Figure 06.02.01.04-8-A6—MEGEVE Steam Generator - Void Fraction Correlation

[ ]

Figure 06.02.01.04-8-A7—MEGEVE Steam Generator - Circulation Ratio

ATTACHMENT B
ON-SITE TESTS

B1 Introduction

In addition to experiments and mock-up tests described in Attachment A of this report, special instrumentation had been installed on one 68/19-type SG at PALUEL1 (1300 MWe plant) to validate the computer codes and the correlations used by AREVA NP to design the SGs and to compare predicted and measured parameters in boiler configuration.

The tests and obtained results performed at PALUEL 1 SG, which have been used to qualify AREVA NP codes, are described in this attachment.

B2 Main Objectives of the Tests

The main parameters studied during the tests are as follows:

- Operating parameters (circulation ratio, saturation pressure).
- Local thermal-hydraulic parameters (carry-over, carry-under, distribution of feedwater and recirculation water in the downcomer, and thermal-hydraulic parameters above the tubesheet).
- Performance of primary and secondary moisture separation equipment.
- Overall SG response to transients (reactor trip, load rejection, switching from normal to auxiliary feedwater).

B3 Description of the Instrumentation

Instrumentation and purposes of instrumentation are as follows:

- Secondary flow velocity measurements (pseudo Pitot allowing measurement of total and static pressure in flow) in the lower and in the upper part of the downcomer.
- Internal thermocouples and surface temperature detectors at different elevations of the downcomer.
- Tubesheet temperature and pressure near the top of the tubesheet, measured by means of sampling probes inserted into the SG through inspection holes. These probes are also used for water sampling for chemical analysis purposes.

- Absolute and differential pressure measurements at different SG elevations, to determine pressure drops in the whole recirculation loop, including those of the primary separation equipment.

The detailed instrumentation of PALUEL 1 SG is illustrated in Figures 06.02.01.04-8-B1 through 06.02.01.04-8-B4.

B4 Tests Performed

Numerous tests at PALUEL 1 have been performed under steady-state and transient (load rejection, reactor trip) conditions during unit start-up, during power escalation and during normal operation all throughout the entire first fuel cycle.

B5 Tests Results

The main information resulting from these numerous tests and the analysis of their results are summarized below:

- [

  ]
- [

  ]

Figure 06.02.01.04-8-B1—Instrumentation of PALUEL Unit 1 Steam Generator

	ITEM	NUMBER
- Fluid Pressure	FP	4
- Upper Deck Pressure Losses	UDPL	2
- Primary Separator Pressures Losses	PSPL	2
- Pressure Losses	PL	2
- Pressure Losses at bundle entrance	PLTBE	2
- Pressure Losses along Tube Sheet Radius	PLTSR	2
- Void Fraction	VF	2
- Water Level	WL	2
- I.D. Thermocouple	IDT	38
- O.D. Thermocouple	ODT	66
- Fluid Velocity	FV	8
- Accelerometers	A	1
- Sampling	S	20

Figure 06.02.01.04-8-B2—Instrumentation of PALUEL Unit 1 Steam Generator

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Figure 06.02.01.04-8-B3—Instrumentation of PALUEL Unit 1 Steam Generator

Figure 06.02.01.04-8-B4 Instrumentation of PALUEL Unit 1 Steam Generator

Figure 06.02.01.04-8-B5—PALUEL Unit 1 Steam Generator– Comparison Between Calculated And Measured Circulation Ratio

Figure 06.02.01.04-8-B6—PALUEL Unit 1 Steam Generator– Comparison Between Calculated And Measured Saturation Pressure

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